Pluggable DWDM: Considerations For Campus and Metro DCI Applications

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Platform Datacenter Optics

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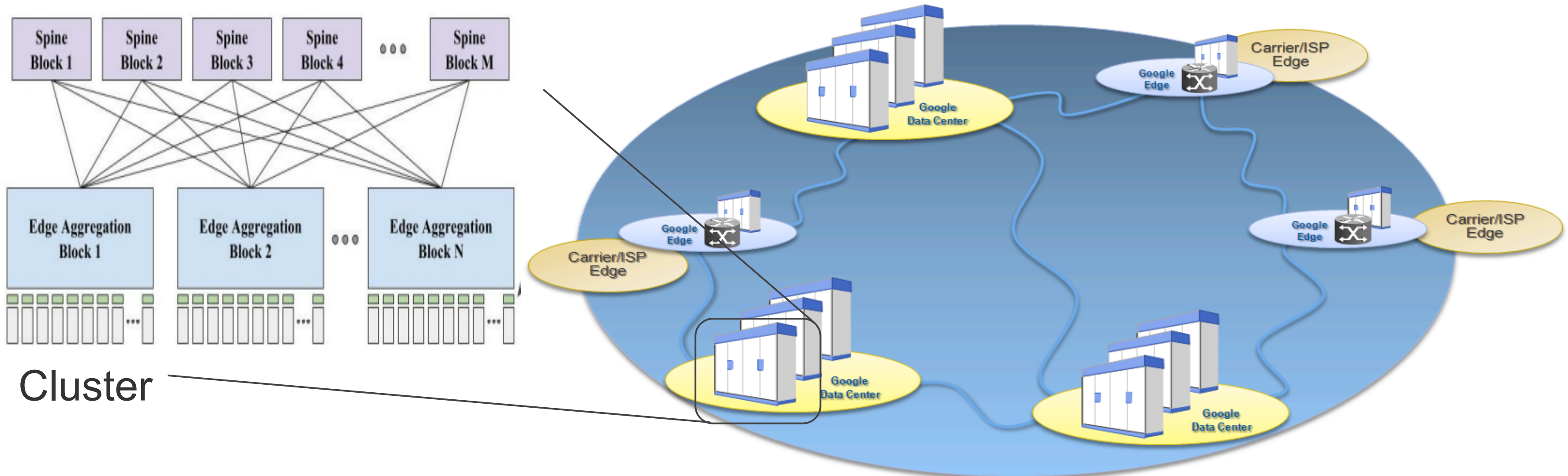
Google DC Interconnection Network

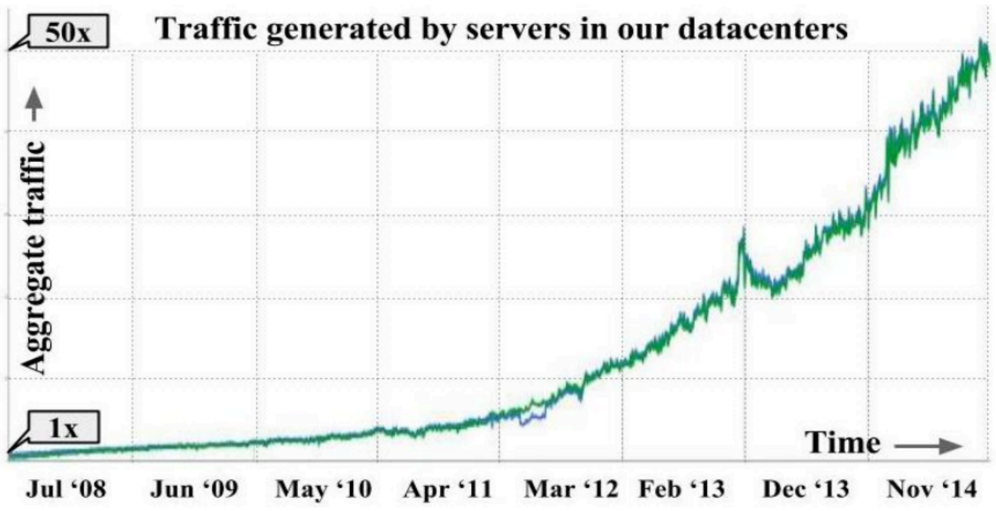
Intra-DC (Clusters)	Inter-DC (Campus)	DC to Backbone (Metro)	Global Inter-DC (Backbone, LH)
500m-1km	2km	80km	1000s km

Distance →



Google Datacenter Traffic Growth

Google



- Datacenter traffic has increased 50x from 2008 to 2014
- Roughly doubling every year.
  - Faster than Internet growth

Datacenter Campus Network (today)

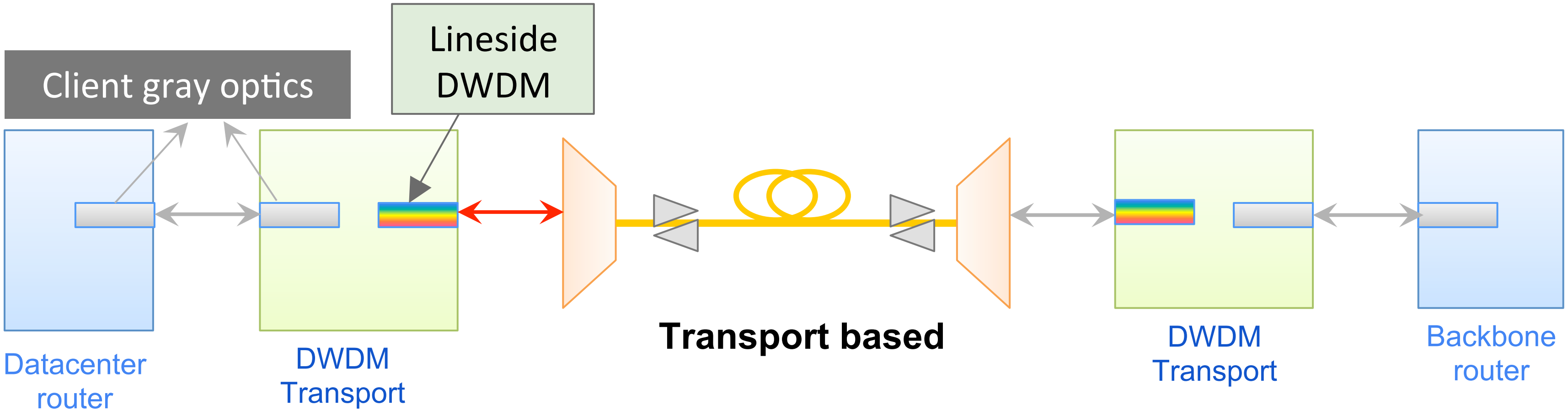
Google's Perspective

Google Oklahoma data center campus

- Interconnecting multiple DCs with geographic proximity (~2km)
- One or multiple warehouse computers (Clusters) within each DC
  - Google Jupiter cluster provides 1.3 Petabits bisection bandwidth
- Interconnection technique
  - Pluggable gray optics (typical)
  - Single mode fiber

Edge access (Metro) network (today)

Google



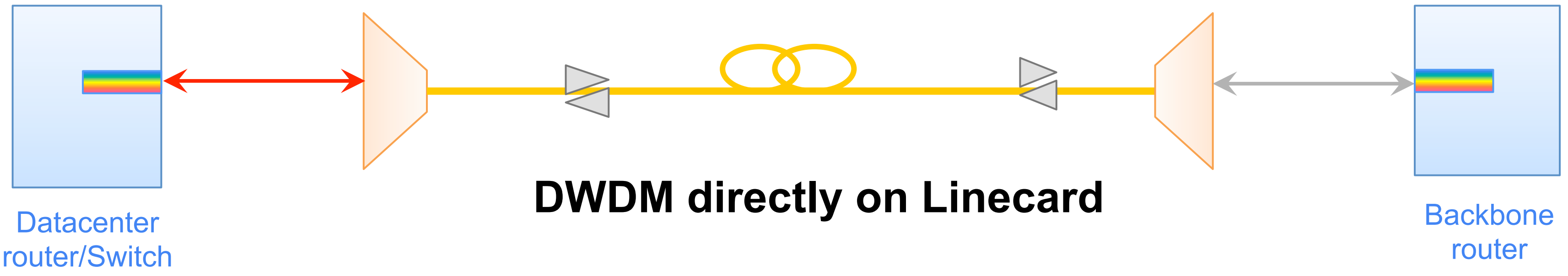
- Interconnecting datacenter/POP and backbone (~40 - 80km)
- Traditional DWDM transport technique
  - Grey Optics for client side, colored DWDM optics for line side
  - Client side speed typically smaller than lineside speed

Challenges Facing Current Solutions

Google

- Bandwidth scaling challenge for DCI campus
  - Fiber exhaustion problem
    - Pulling new fiber is expensive
    - Pulling new fiber also constrained by physical conditions
- Cost scaling challenges for DCI Metro (edge access)
  - Muxponder based DWDM optimized for traditional telecom Metro, where
    - reach up to 300-600km
    - client speed significantly slower than lineside speed
  - Not optimal for DCI metro, where
    - reach only ~40 - 80km
    - client speed equal (or close) to the lineside speed

Emerging Technical Trend



- DWDM directly on router and switch card (pluggable DWDM)
  - Eliminating client interconnection and terminal chassis (reduce cost, power)
  - Allowing simpler management and control
  - Potential use for both campus and Metro

Pluggable DWDM: Performance Metrics

Google

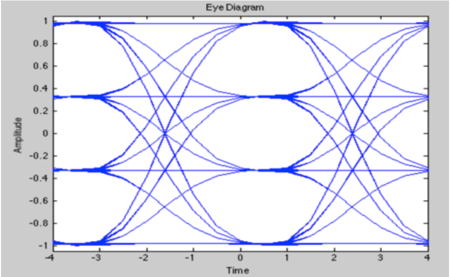
Google's Perspective

- Cost
- Power, Size and Density
  - DC grey optics form factor
- Wavelength Tunability
- Link performance (OSNR, dispersion tolerance etc)
- Spectral Efficiency (less important than LH)

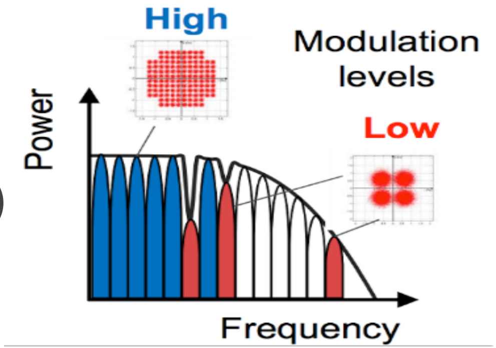
100G Tunable QSFP28: Enabling Technologies Google

- ❑ Serial 100Gb/s direct modulation with 16nm CMOS
  - 50-Gbaud PAM4 [1]
  - 50-Gbaud (equivalent) DMT
- ❑ Lower power and small footprint tunable lase
  - With relaxed power,wavelength stability and phase noise requirements
- ❑ FBG based full C-band tunable DCM (in line systems)

[1] over 80km performance demonstrated: D. Sadot et al, OE 2015



PAM4



DMT (courtesy to Socionext)

Revisit Optical Dispersion Compensation

- Multi-span DWDM systems
  - Require optical DCM every span
  - Additional tunable DCM
  - Cost is high compared to electrical dispersion compensator
- Single-span DCI Metro
  - Single broadband tunable DCM (FBG based technology)
  - Cost and power shared by 40-80 channels
    - Likely lower than electrical dispersion compensator
  - Reduce transceiver power
    - Help meet stringent power density requirement of pluggable optics

Broadband TDCM

Beyond 100G: Coherent or Direct Detection ?

Google

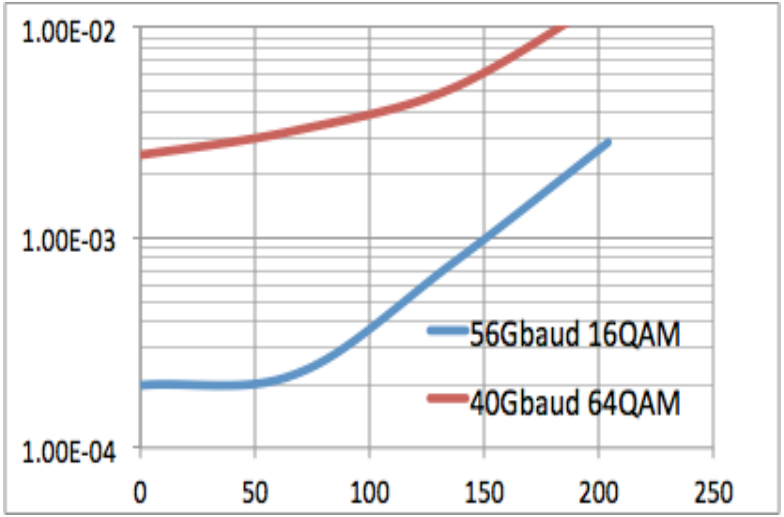
- Direct detection
  - Require multiple tunable lasers (four for 400G !)
    - Cost and power likely high
  - Spectral efficiency (SE) difficult to scale
    - Single sideband modulation could double SE but complex Tx design
- Coherent detection
  - Single tunable laser for 400G (shared by both the signal and the LO !)
    - More stringent laser performance
  - Higher spectral efficiency (2-4 times higher)
  - Support greater link loss (better OSNR sensitivity)
  - High DSP power: extra power for pol. and phase recovery

Ultra-Low Power Coherent DSP

Google

- 7nm CMOS node
- Baud-rate or minimum over-sampling DSP
  - Baud-rate DSP achieves the lowest power consumption but has limited dispersion compensation capability
- Minimal MIMO EQ tap length
- Less powerful FEC
- 2/3-bit DAC for 16/64-QAM
- Remove OTN framer

With Baud-rate DSP



Residual CD (ps/nm)

Conclusions

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- Grey optics DC campus interconnection faces bandwidth scaling challenges
- Pluggable (and tunable) DWDM is a promising solution for both campus and Metro without sacrifice of router and switch port density
- PAM4/DMT based serial 100G could enable 100G tunable QSFP28
- 7nm ultra-low power coherent DSP likely enables 400G pluggable DWDM